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## Local land-use decision-making in a global context

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TOPICAL REVIEW • **OPEN ACCESS**

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Supplementary material for this article is available [online](#)

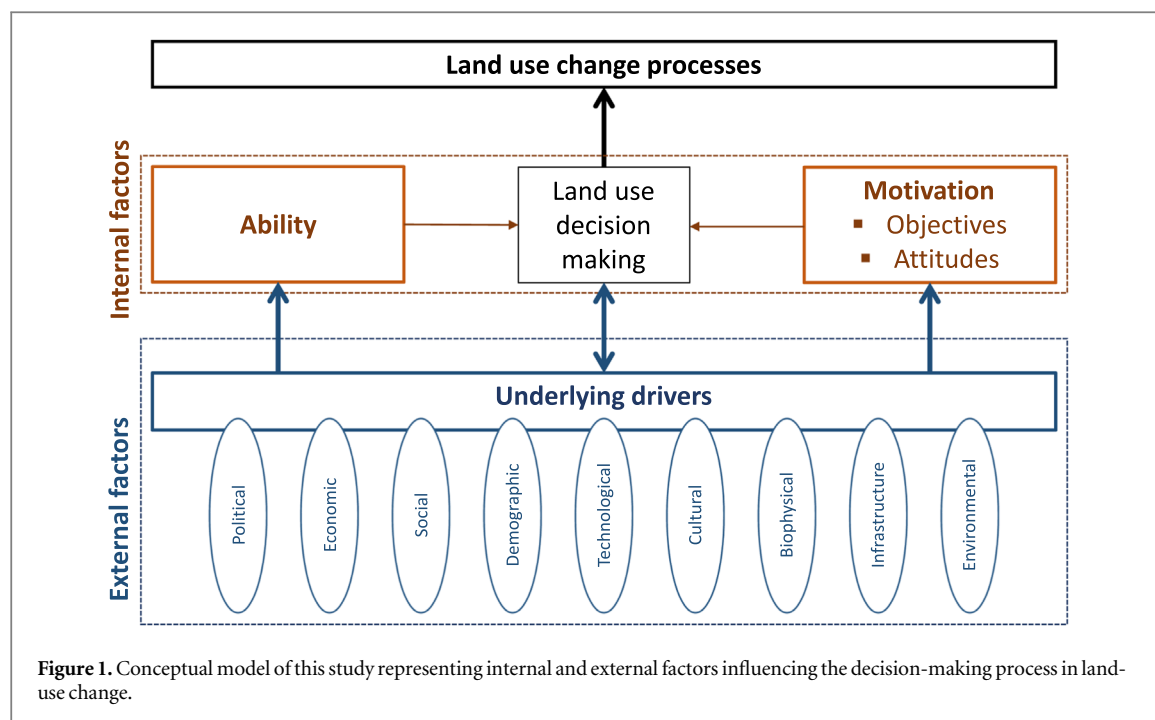
## Abstract

Land-use change has transformed the majority of the terrestrial biosphere, impacting biodiversity, climate change, food production and provision of multiple ecosystem services. To improve our understanding of land-use change processes, the motivations and characteristics of land-use decision-makers need to be addressed more explicitly. Here, we systematically review the peer-reviewed literature between 1950 and 2018 that documents decision-making underlying land-use change processes. We found 315 publications reporting on 559 case studies worldwide that report on land-use decision-making in sufficient depth. In these cases, we identified 758 land-use decision-makers. We clustered decision-makers based on their objectives, attitudes and abilities into six distinct types: survivalist, subsistence-oriented smallholder, market-oriented smallholder, professional commercialist, professional intensifier and eco-agriculturalist. Survival and livelihood were identified as most common objectives for land-use decision makers, followed by economic objectives. We observe large differences in terms of decision-makers' attitudes towards environmental values, and particularly their financial status, while decision makers have a generally favorable attitude towards change and legislation. The majority of the documented decision-makers in the literature have only few abilities as they are poor and own small plots of land, while the wealthier decision-makers were identified to have more power and control over their decisions. Based on a representativeness analysis, we found that decision-making processes in marginal areas, such as mountainous regions, are overrepresented in existing case study evidence, while remote areas and lowlands are under-represented. These insights can help in the design of better land-use change assessments, as well as to improve policies towards sustainable land use.

## 1. Introduction

Land-use change (LUC) affects the environment at global, regional and local scales. Changes in land-use, and resulting changes in land cover, can have far-reaching implications, including biodiversity loss, soil degradation, decreased agricultural productivity, and increased risk of flooding (Guo and Gifford 2002, Ambinakudige and Choi 2009, Meyfroidt 2013). LUC is the direct outcome of human decisions, which are influenced by a variety of context-specific socio-economic and biophysical drivers and processes. Consequently, the importance of understanding the decision-making processes underlying human LUC

has been widely acknowledged (Knowler and Bradshaw 2007, Hersperger *et al* 2010, Baumgart-Getz *et al* 2012, van Vliet *et al* 2016). Several studies have reviewed case-study findings to synthesize particular LUC processes (van Vliet *et al* 2016). However, most of these explain LUC primarily in terms of underlying drivers and/or biophysical conditions (Barbier and Burgess 2002, Lambin and Geist 2006, Rey Benayas 2007, Helldén and Tottrup 2008, Yang and Wu 2012, Munteanu *et al* 2014, Robinson *et al* 2014, van Vliet *et al* 2016). Several authors have pointed out that similar combinations of underlying drivers and biophysical conditions may lead to different land-use decisions (Hersperger and Bürgi 2009, An 2012, van



**Figure 1.** Conceptual model of this study representing internal and external factors influencing the decision-making process in land-use change.

Vliet *et al* 2015) and that driving factors and biophysical conditions alone cannot fully explain the observed LUC (Geist and Lambin 2002, 2004, Rudel 2007). This variation may be explained by characteristics and attitudes of the involved decision-makers who directly change land (Knowler and Bradshaw 2007, van Vliet *et al* 2015, Hettig *et al* 2016). While there is a rich body of conceptual studies (Meyfroidt 2013, Groeneveld *et al* 2017) as well as local case studies in different environments documenting how in local contexts land-use decisions are made, there is no global overview of how these characteristics and attitudes influence land-use decisions around the globe.

In this paper we present a systematic review of LUC case studies, in which we analyze the characteristics of land-use decision-makers, the underlying drivers that influence these land-use changes, and the objectives, attitudes and abilities that affect the decisions, at a global scale. We conceptualized the relation between decision makers and LUC as either a specific chain of events (driving forces influence the actor who subsequently causes change) or an interplay between driving forces and the actor (figure 1, see S1 is available online at [stacks.iop.org/ERL/14/083006/mmedia](https://stacks.iop.org/ERL/14/083006/mmedia) for more detail), following Hersperger *et al* (2010). While many conceptualizations of decision-making exist, three internal factors determining decision-making processes are part of many conceptual frameworks: the actors' motivation, subdivided in objectives and attitudes, and the ability to carry out a decision (Ajzen 1991, Valbuena *et al* 2010, Milner-Gulland 2012, Müller *et al* 2013, Groeneveld *et al* 2017, Müller-Hansen *et al* 2017). The actors' motivation towards a decision can be influenced by a multitude of personal objectives and attitudes. The more positive the attitudes towards an intended behavior are, the

more likely the behavior towards reaching the personal objectives will be. Besides, a decision-maker needs to be able to act upon any intended decision (Ajzen 1991). We therefore coded reported attitudes and objectives per case and also coded the decision-maker's ability by looking at their assets (e.g. financial capital, land size) and social resources (e.g. social network, power) (Scoones 2009). Underlying driving forces are overarching external factors that influence the decision-making process, which have been identified for many different land use change processes (Geist and Lambin 2002, Asselen *et al* 2013).

## 2. Methods

This systematic review was conducted by taking the following steps: (1) identification of eligibility criteria of case studies, (2) systematic literature search in Web of Science, (3) data collection and coding, and (4) analysis and synthesis of the coded information. This study design follows the steps prescribed by the PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses, (Moher *et al* 2009)), for which the full details are provided in the supplementary material (S2).

### 2.1. Eligibility criteria

We looked for articles that report on local case studies of land-use change from the period 1950–2018 that explicitly account for at least one land-use decision-maker. Specifically, articles were considered eligible when they contained information on (1) the actor's internal decision-making process (objectives, attitudes and abilities influencing the decision process); (2) driving forces underlying the reported land use

change, and (3) a documentation of the land-use change itself including the extent and study period.

## 2.2. Systematic literature search

We systematically searched for peer-reviewed articles using Web of Science (as being the most common in systematic reviews). First, we conducted a broad literature review on studies documenting local land-use change and decision making to identify relevant search keywords that were related to studies that matched our eligibility criteria. Based on this scoping, our knowledge of the literature in the field and initial searches in Google Scholar we identified 72 articles that were considered both relevant in terms of data provision and heterogeneous with regard to scientific disciplines. These articles were used to iteratively develop a search string that was able to return all of these papers:

- (1) (chang\* OR dynamic\* OR driving\*force\* OR decision\* OR impact\* OR disturbance)  
AND
- (2) ('climate change' OR 'land use' OR LUC OR LCLUC OR LULCC OR landscape\* OR land)  
AND
- (3) (farming OR agricultur\* OR degradation OR \*forest\* OR horticulture\* OR pasture\* OR live-stock OR urbanization OR desertif\* OR \*intensification OR 'farming system' OR wetland\* OR livelihood\*); LANGUAGES: ( ENGLISH ) AND DOCUMENT TYPES: ( ARTICLE ); Timespan: 1950–2018.

The result of this search (117614 articles) was further narrowed down by excluding studies on biology, health sciences, geology and other earth sciences, as that was deemed too far from our scope (see S3 for full search string). The systematic search of Web of Science returned 9710 articles. Selection based on the titles yielded 3019 articles for abstract reading. Further selection based on abstracts resulted in 968 articles that were eligible for a full-text assessment, from which 315 articles were found eligible for coding as they contained sufficient information on decision-making mechanisms (S4).

A second reviewer independently checked 5% of studies that were considered eligible by the first reviewer in each round. Differences between coders were discussed to refine inclusion criteria until the disagreements were resolved, in order to ensure consistency in the process.

## 2.3. Data collection and coding

Articles were coded in terms of (1) publication information (author, publication year, study title), (2) type of research (discipline, methods used), (3) information on the case-study site (geographical

information, landscape characteristics), (4) number of decision-makers responsible for land-use change and (5) time-period. Articles that report on several case study locations (e.g. comparative studies) were coded as separate cases. For each case, reported land-use decision makers (e.g. farmer) or groups of decision makers (e.g. farming cooperative) that show divergent objectives, attitudes and/or abilities from other actors in the same case study were considered as a separate decision-maker and were coded separately. Furthermore, decision-makers who change their internal factors over time leading to two distinct modes of decision-making were considered largely independent and thus coded separately.

Internal factors influencing decision making were assessed by objectives, attitudes and ability (table 1, details on the coded variables are provided in S5). Objectives were coded by dividing 10 points over all objectives, proportional to their contribution to the land-use decision. Attitudes and abilities were coded on a 10-point Likert scale. Objectives, attitudes, and abilities were coded quantitatively to be able to compare across decision makers and facilitate the identification of decision-making types. As the importance of these factors is often nuanced and cannot be simply captured by a binary presence/absence coding. For example, financial abilities (capital) ranged from extreme poverty to extremely wealthy, which cannot be represented in Boolean values only. The difference in coding between objectives on the one hand and attitudes and abilities on the other, reflects the way in which in many cases decision-making is described: while the objectives are mutually exclusive (you cannot adhere fully to economic objectives and fully to lifestyle objectives at the same time), the attitudes and abilities are not by definition mutually exclusive.

*Objectives* refer to a goal related to a certain human need and are sub-divided into survival and livelihood security (defined as the safeguarding of the minimal requirement of subsistence), economic objectives, environmental objectives, lifestyle objectives, and social prestige. *Attitudes* refers to a settled way of thinking or feeling. We differentiate between the attitude towards change, the attitude towards legislation and the attitude towards environmental values. Attitude towards legislation describes how decision-makers are adherent or skeptic to rules or institutional norms. Environmental values define how much the decision-makers value the environment (Ives and Kendal 2013). *Ability* represents the availability of material assets and social resources to implement an intended decision (Scoones 2009, Valbuena *et al* 2010). Material assets, which may be expressed by the wealth, income, or land size, are particularly important for the realization of objectives. Similar parameters are used in computational models to explain land-use change (Boumans *et al* 2002, Murray-Rust *et al* 2014). Social resources, include connectivity, power, and action control. To pursue different land-

**Table 1.** Variables used to code decision-making mechanisms.

Internal factors	Internal factor components	Description
Objectives (10 points distributed among 5 objectives)	Survival and livelihood security	No survival/livelihood objectives (0) to only survival/livelihood objectives (10)
	Economic objectives	No economic objectives (0) to only economic objectives (10)
	Environmental objectives	No environmental objectives (0) to only environmental objectives (10)
	Lifestyle objectives	No lifestyle objectives (0) to only lifestyle objectives (10)
	Social prestige	No social prestige objectives (0) to only social prestige objectives (10)
Attitudes	Attitude towards change <sup>a</sup>	Very conservative (1) to very progressive (10)
	Attitude towards legislation <sup>a</sup>	Very negative attitude towards legislation (1) to complete following of legislation (10)
	Attitude towards environmental values <sup>a</sup>	Very low attitude towards environmental values (1) to high attitude towards environmental values (10)
Ability	Wealth <sup>a</sup>	Extreme poverty <sup>b</sup> (1) to extremely wealthy (10)
	Land size <sup>a</sup>	Less than 2 ha (1) to more than 500 ha (10)
	Land tenure security <sup>a</sup>	Unclear or insecure land tenure security (1) to secure land tenure (10)
	Social connectedness <sup>a</sup>	Low social connection (1) to high social connection (10)
	Power status <sup>a</sup>	Low societal power status (1) to high societal power status (10)
	Action control <sup>a</sup>	Restricted action control (1) to high freedom of action control (10)

<sup>a</sup> Indicate factors coded on a 10-point Likert scale.

<sup>b</sup> The variable extreme poverty is based on the international poverty line of earning less than 1.90 \$ per person per day as defined by the World Bank Purchasing Power Parity of 2011 (Ferreira *et al* 2012).

use decisions, people may draw upon social resources such as sharing family labor (Hussain and Hanisch 2014), joint ventures between commercial farmers and farm workers (Debbané 2013), cooperatives (Fujisawa *et al* 2015) or systems to exchange products (e.g. between pastoral communities and farmers in remote areas (Wiegiers *et al* 1999)).

We coded underlying driving forces as political, economic, social, demographic, technological, cultural, biophysical, infrastructure, and environmental factors. The outcomes of the land-use decisions are coded as one of the following land-use change processes: deforestation, reforestation, agricultural land abandonment, land degradation, urbanization, agricultural intensification, and agricultural disintensification. Agricultural intensification was defined as higher levels of inputs including fertilization, irrigation, mechanization and pesticides (Lambin and Geist 2006), and disintensification as the process of decreasing the use of input levels relative to land area (Eurostat 2017). Agricultural land expansion has not been coded as a separate land-use change as in the majority of cases this was associated with deforestation.

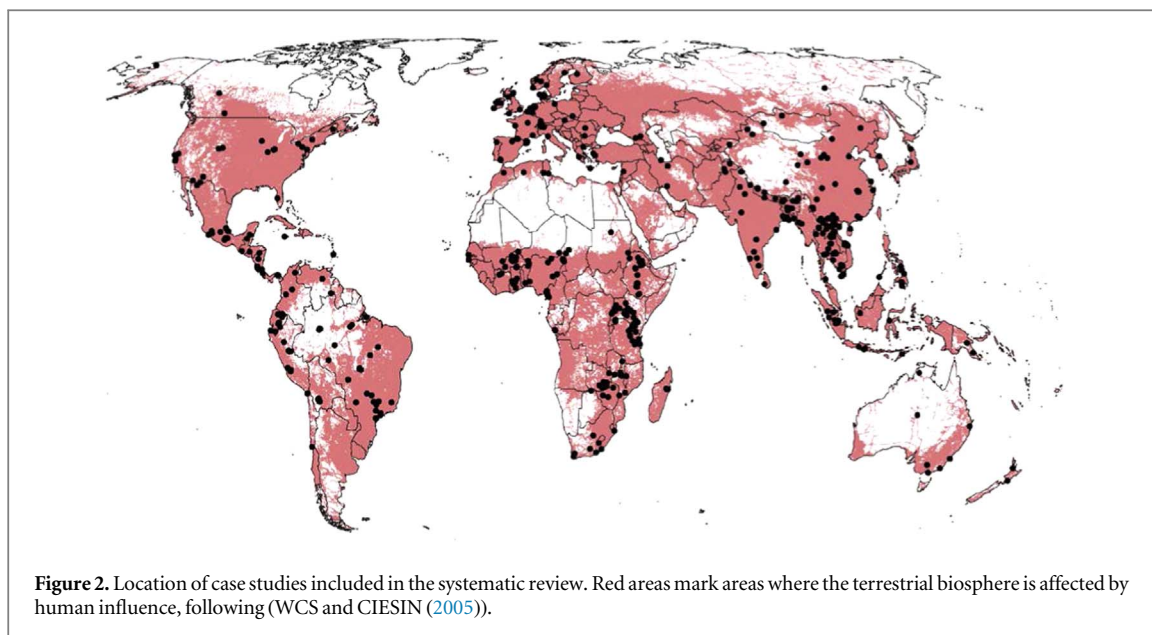
## 2.4. Analysis and synthesis

Results of the coding were initially analyzed in terms of their descriptive statistics. Subsequently we further analyzed the coding result by means of a cluster analysis and a representativeness analysis. A cluster analysis was used to construct a typology of decision-

makers on land-use change based on their motivations, attitudes and abilities. Typologies are a common approach to synthesize variation in decision-making in land-use change (Heimlich and Anderson 2001, Busck 2002, Smithers and Johnson 2004, López-i-Gelats *et al* 2015). We standardized all coded variables and used hierarchical agglomerative clustering methods, by computing the similarity between any pair of decision-makers through the Euclidean Squared Distance measure (Köbrich *et al* 2003). We applied the four mostly used hierarchical agglomerative methods, single linkage, complete linkage, average linkage, and Ward's method, to explore the stability of clusters (Aldenderfer and Blashfield 1984). To determine the number of clusters in the data set we plotted a scree plot based on the coefficients of the agglomeration schedule and implemented the elbow method (Mooi and Sarstedt 2011). We conducted significance tests on the clustered variables in order to discern the variation among the clusters. A series of multivariate analyses of variance (MANOVAs), was performed to evaluate the accuracy of the clusters and to statistically assess the differences among the groups.

Potential publication biases from the articles that have been included in the systematic review have been assessed with help of a representativeness analysis. Representativeness is considered in terms of how well the selected case studies represent global patterns of land-use, biophysical and socio-economic factors (S6). All maps that have been used to conduct the representativeness analysis have a global terrestrial





coverage, and have been resampled to a resolution 5 arc minutes (corresponding to  $9.25 \times 9.25$  km at the equator) using an equal area Eckert IV projection. We conducted a Kolmogorov–Smirnov test (K–S test), a nonparametric goodness-of-fit test, to assess statistically whether the observations from the systematic review sample could reasonably have come from a global distribution (Schmill *et al* 2014). Thousand random samples of the same size as the systematic review sample were generated and the K–S statistic and *p*-value for each sample was computed.

### 3. Results

The 315 papers included in our review (S7) reported on 559 case-study locations (figure 2) and 758 different land-use decision-makers. A third (34%) of the case studies are located in Asia, with 38 in China and 31 in Vietnam. Case studies located in Africa follow with 28%, including 19 case study locations in Ethiopia, 15 in Burkina Faso and 14 in Cameroon, Tanzania and Kenya. Europe hosts 14% of the case studies and South America 13%. North and Central America (9%) and Australasia (2%) are less represented in the sample than other world regions. Concentration of case study locations in some regions is apparent, such as in Eastern Africa and in Southeast Asia (figure 2).

#### 3.1. Descriptive statistics of land use decision makers and land-use change processes

Most decision-making in our sample takes place at the household level (91%). Corporations, e.g. oil companies represent 6% of the decision-makers. Only 3% of our cases report joint decision-making at community level. We found a range of land-use changes linked to these decision-making modes (table 2). More than half of the decisions on LUC are related to agricultural land, including 41% agricultural intensification, 13%

agricultural disintensification, and 4% agricultural land abandonment. Decisions on deforestation, mostly linked to the clearing of forest to reclaim agricultural land, were taken by 22% of the actors. Furthermore, we recorded 11% of the actors to be involved in reforestation and vegetation recovery and 5% in urbanization. Reforestation and urbanization in this case mostly refer to small-scale changes such as adding trees and holiday homes, rather than large scale forest plantations and urban expansion. A minor fraction of decision-making resulted in land degradation.

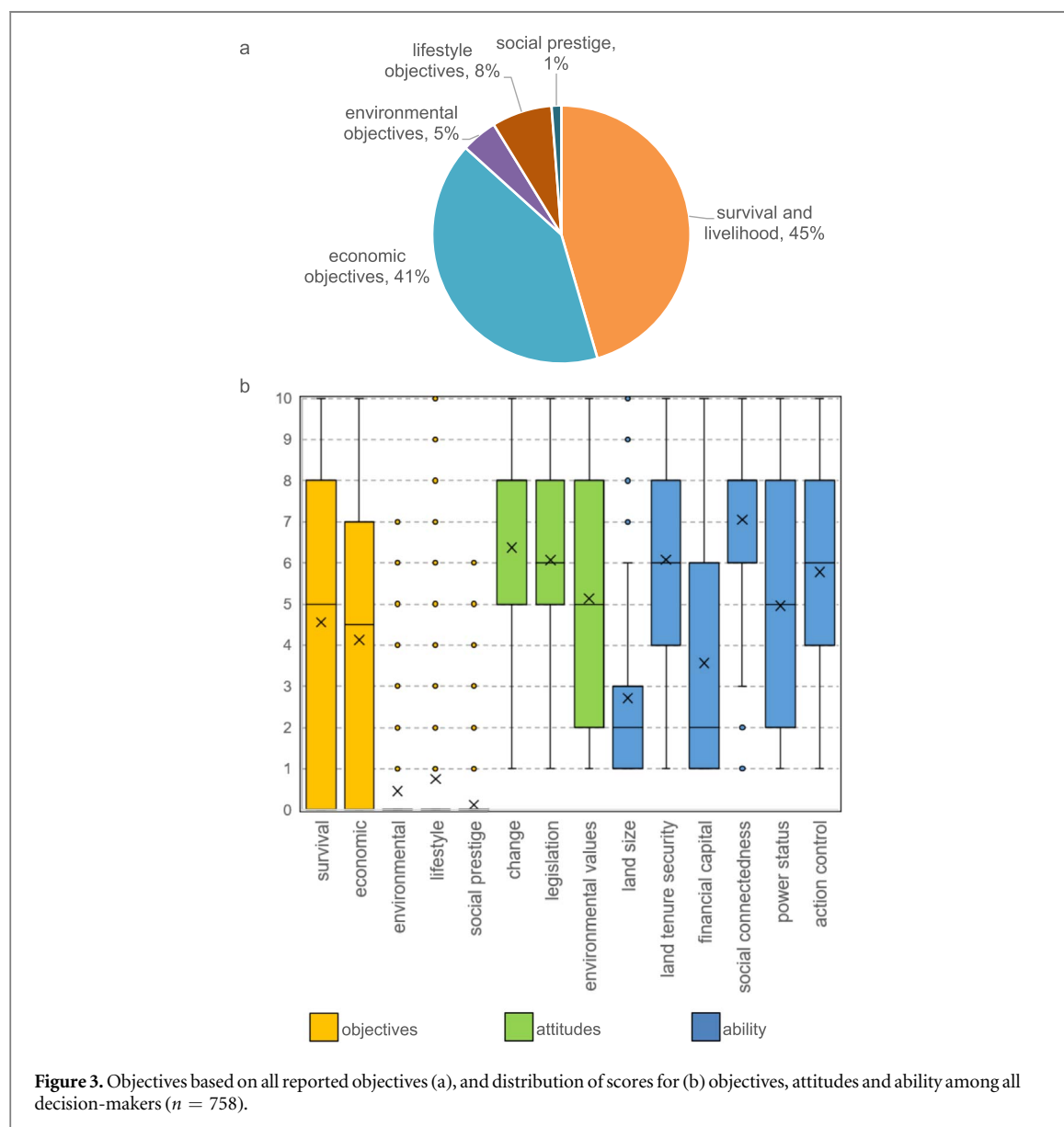
##### 3.1.1. Drivers underlying land use change decision making

Economic (34%) and political (19%) driving forces were most often reported across all case studies and influence agricultural land intensification, disintensification and reforestation, in particular. Demographic (12%) forces follow, and are important for deforestation, abandonment and disintensification. Biophysical forces are reported in relation to desertification and land degradation processes, while other driving forces play smaller roles (S8).

Internal factors affecting the decision-making process. Internal factors affecting land-use decision making (i.e. objectives, attitudes and ability), were interpreted in terms of their relative importance, with 10 points distributed across the objectives and with a 0 indicating no importance, and 10 indicating essential importance for attitudes and ability. The most important objectives for land-use change decisions reported are survival and livelihood (mean 4.6, SD, 3.9) and economic objectives (mean 4.1, SD 3.5). The high standard deviations indicate the variability within our sample (S9). Environmental objectives (mean 0.5, SD 1.2) were mentioned in only 16% of the decision-making cases, and only 3% of decision-makers considered

**Table 2.** Counts and percentages of main LUC per actor and reported underlying driving forces (drivers that occurred in >15% of the cases per land use change are reported in order of importance).

Land-use change	Number of decision makers reported ( <i>n</i> = 758)	% of all decision makers reported	Underlying drivers
Agricultural intensification	314	41%	Economic and political
Deforestation	165	22%	Economic, demographic and political
Agricultural disintensification	96	13%	Economic, social and biophysical
Reforestation and vegetation recovery	93	12%	Political, economic and biophysical
Urbanization	40	5%	Economic, political, cultural
Agricultural land abandonment	34	5%	Economic, social and demographic
Land degradation	16	2%	Economic, demographic and biophysical



them important (score  $\geq 5$ ). Overall, 5% of the points that could be distributed amongst the objectives were distributed to environmental objectives (figure 3). Lifestyle (mean 0.8, SD 1.9) and social prestige (mean 0.1, SD 0.7) are not important for the majority of

decision-makers: while in 18% of the decision-makers lifestyle objectives were mentioned, only 8% considered lifestyle as the most dominant objective (score  $\geq 5$ ). Social prestige is observed by only 4% of



the decision-makers, and in only 1% it is reflected in a considerable manner (score  $\geq 5$ ).

The majority of the LUC decision-makers show positive attitudes towards change (67% with a score  $>5$ , mean 6.4 SD 2.6; figure 3, S9). The generally positive attitudes towards change reflect that most studies focus on land-use change; thus a bias toward high scores on change attitude in the sample is likely. More than half (59%) of the sample shows a positive attitude towards legislation (score  $> 5$ ). The mean of environmental attitudes of 4.9 reflects an overall neutral attitude towards environmental values, with 47% of decision-makers showing a positive attitude.

Most of the decision-makers in our sample are poor with little financial means (71% with score  $< 5$ ), with 28% living below the poverty line. Only 17% of the decision-makers can be considered wealthy ( $>8$ ) and 2.5% are extremely wealthy ( $=10$ ). The low mean of financial ability (3.6, S9) reflects the high amount of poor people in the cases, with a possible explanation that indigenous communities are frequently studied (38% of our sample). The standard deviation of 2.7 indicates the high variation in financial assets or capital among the decision-makers. The majority of the decision-makers (84%) only own small plots of land ( $<5$ ), with 37% cultivating less than 2 ha (score = 1). Only 11% of the decision-makers cultivate more than 150 ha. More than half (60%) of the land-use decision-makers enjoy a stable land tenure security ( $>5$ ). Unstable land tenure security is in the case-studies often connected to political riots, lack of minority rights, squatting (Muriuki *et al* 2011), and land grabbing (Angassa and Oba 2008).

Most of the land-use decision-makers (76%) are well connected (S9). The mean of connectedness is 7.1 (SD 2.5), indicating a rather good network connection across all decision-makers. However, almost a half of the decision-makers (47%) have a low power factor ( $<5$ ) in social decisions. Decision makers that do not have a high likeliness to realize their own will in a public decision (e.g. minority groups who have a low power factor) tend to seek support from a broad social network, which explains the general high social connectedness among actors across all case studies. Similarly, 32% of the land-use change actors report little control on their actions (score  $< 5$ ).

Not all studies reported stable decision-making strategies, as we found 26 studies where the decision-makers evolved through time and coded these cases in different time periods separately (37 cases). Changes in either objective, attitude or ability were often triggered by political transitions (e.g. collapse of socialism in Romania (Stringer and Harris 2014)) or wars (civil war in Sierra Leone (Wilson and Wilson 2013)). The 37 cases with temporal changes in decision-making lead to 101 coded decision-making cases. Additionally, we identified 18 cases where a decision-maker only was reported in a later period (e.g. a new rubber plantation in Vietnam started by a Chinese company (Friis *et al*

2016)). In cases with temporal changes in decision-making, survival and livelihood became less important over time, with economic objectives becoming more important (figure 4). Within these studies, attitudes towards change and environmental values increased, as well as assets and social resources. At the same time, land size slightly decreased, such as in a number of cases in Eastern Europe where post-socialist land reforms resulted in the collapse of farming associations and restitution of private land to a larger number of new owners (Yakovleva 2011, Lieskovský *et al* 2013, Stringer and Harris 2014, Bucała-Hrabia 2017, Gunya 2017).

### 3.2. A typology of land-use decision-makers

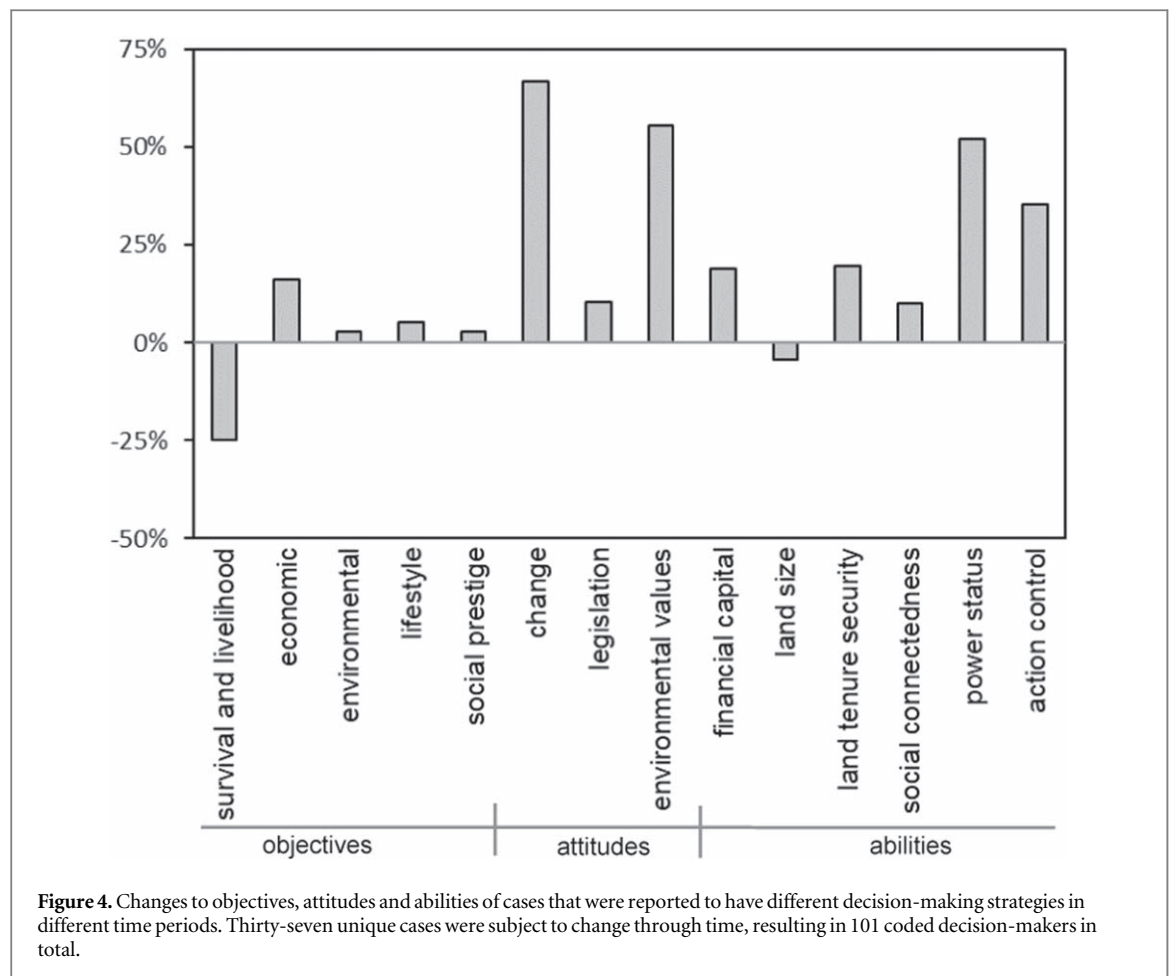
We identified six different decision-making types relevant to land-use change based on typical combinations of objectives, attitudes and ability. Significant differences were recognized in all variables when considered jointly (Wilk's  $\Lambda = 0.009$ ,  $F(70, 2260.779) = 54.02$ ,  $p < 0.001$ ). We named the different types based on their decision-making and the associated underlying drivers and resulting land-use change processes, while acknowledging that these names may hold different connotations. Therefore, the descriptions of the types are leading and the naming just a placeholder. Characteristics of the decision-making types are presented in figure 5 and S10, and the underlying drivers and related LUC in figure 6 and S11.

#### 3.2.1. The survivalist

The survivalist is the most common land-use decision maker encountered in our review, covering 26% of all reported decision makers. Their primary objective is survival and livelihood (mean 8.8). Decision-makers of this type are the most conservative amongst all six types (mean attitude towards change of 5) and are less likely than other types to change their land-use. These decision-makers are the poorest, have the lowest land tenure security, lowest attitude towards legislation, and the lowest power status (figure 5). The low adherence to rules may explain the high rate of deforestation (figure 6). Black Thai farmers in Vietnam (Meyfroidt 2013), who traditionally combine paddy rice farming with shifting cultivation are a typical example of the survivalist. In this typical survivalist example, population growth lead to an increase in agricultural and logging activities, resulting in land degradation.

#### 3.2.2. The subsistence-oriented smallholder

Subsistence-oriented smallholders are predominantly concerned about their survival (mean 6.3) but also aim to achieve some economic gains (mean 2.8). Traditional ecological knowledge is an important factor when taking decisions (mean attitude towards environmental values of 7.2). Decision-makers of this type



are on average innovative with a positive attitude towards change. They can rely on their community but have access to few financial resources (social connectedness mean 8.1; power status mean 4.4, action control mean 6.1). This decision-making type often (in 24% of all cases of this type) causes deforestation while also reporting agricultural intensification (figure 6). For example, Cambodian farmers that shifted from growing rice for subsistence to exporting dried cassava feedstock, thereby clearing forest for agricultural land (Hought *et al* 2012). At the same time, the subsistence smallholder also has the second highest reforestation rate (14%), and overall most reported reforestation cases (27% of all reported reforestation cases).

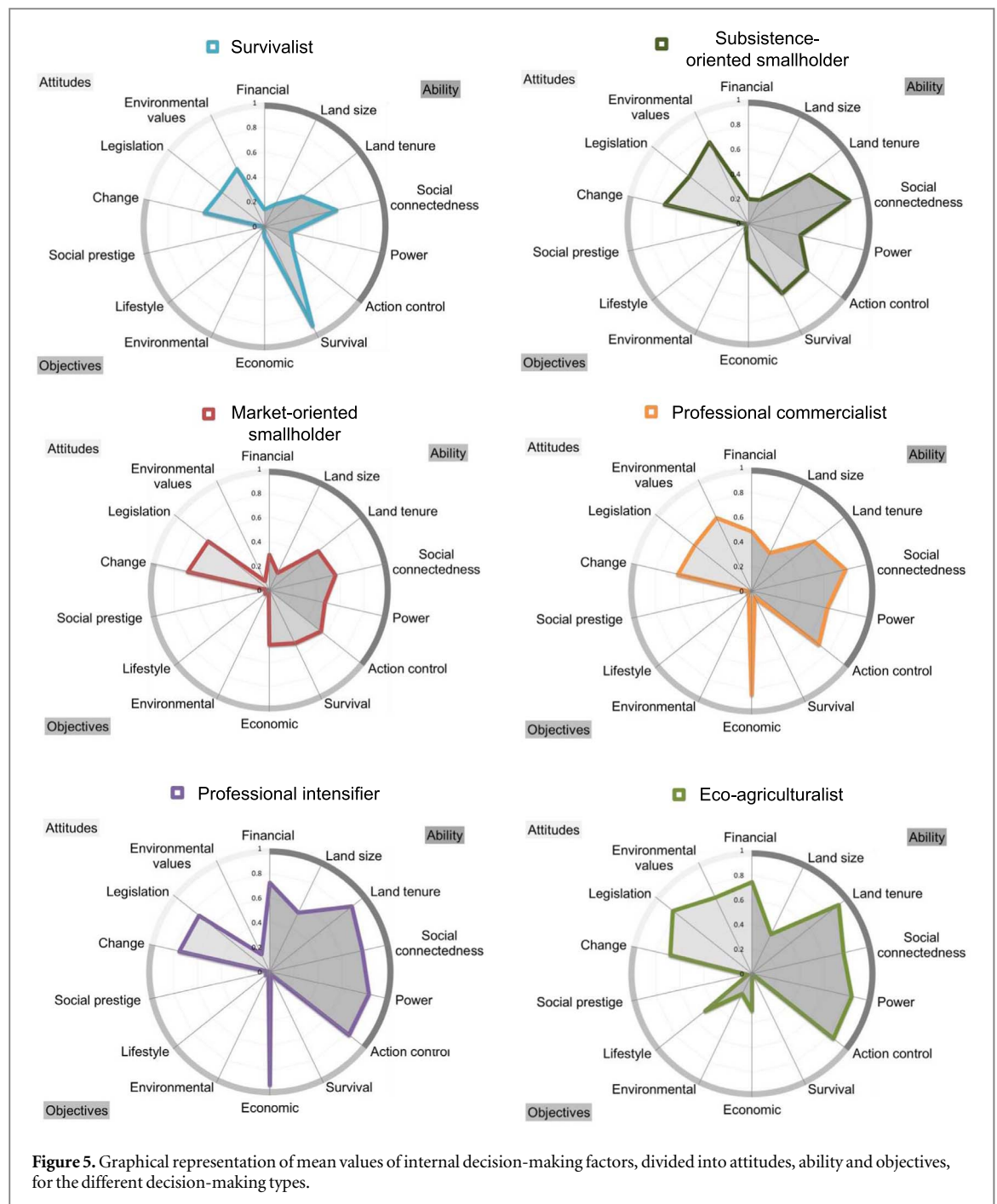
### 3.2.3. The market-oriented smallholder

The main goals of the market-oriented smallholder are twofold: survival (mean 4.9) and economic gain (mean 4.5) (figure 5, S10). The market-oriented smallholders are often in a phase from subsistence agriculture towards a commercial strategy. This decision-making type has little financial means, but is not as poor as the survivalist and subsistence smallholder. The market-oriented smallholder has the smallest land size, and the second lowest tenure security behind the survivalist. This type is on average moderately connected, and progressive (mean attitude towards change of 6.8),

which is reflected in the high willingness to adopt new technology and change the variety of crops according to market demands. Most of decisions taken by this cluster result in intensification (60%). An example of market-oriented smallholders are the Southern Bolivia Altiplano communities (Chelleri *et al* 2016). In this example, the formerly extensive cultivation of quinoa on slopes and grazing land in the valleys, are being replaced by mechanized quinoa monocultures.

### 3.2.4. The professional commercialist

Professional commercialists are relatively wealthy (mean 4.8) with a high appreciation of environmental values (mean 6.6). Typical decision-makers belonging to the professional commercialists are well connected. While most of their decisions relate to agricultural intensification (47%), a significant portion (16%) also results in reforestation with the highest reforestation rate among all decision-making types (figure 6). They are more likely to diversify their land-use activities than professional intensifiers, with whom they share many other characteristics (S12). A typical example of this decision-making type is found for full-time farmers in Denmark (Primdahl and Kristensen 2011) that developed into diversified, more business oriented farms that typically produce food, fiber or bioenergy for the international market. At the same time, the farmers' follow both economic (production) and



environmental and lifestyle objectives (maintaining a livable landscape).

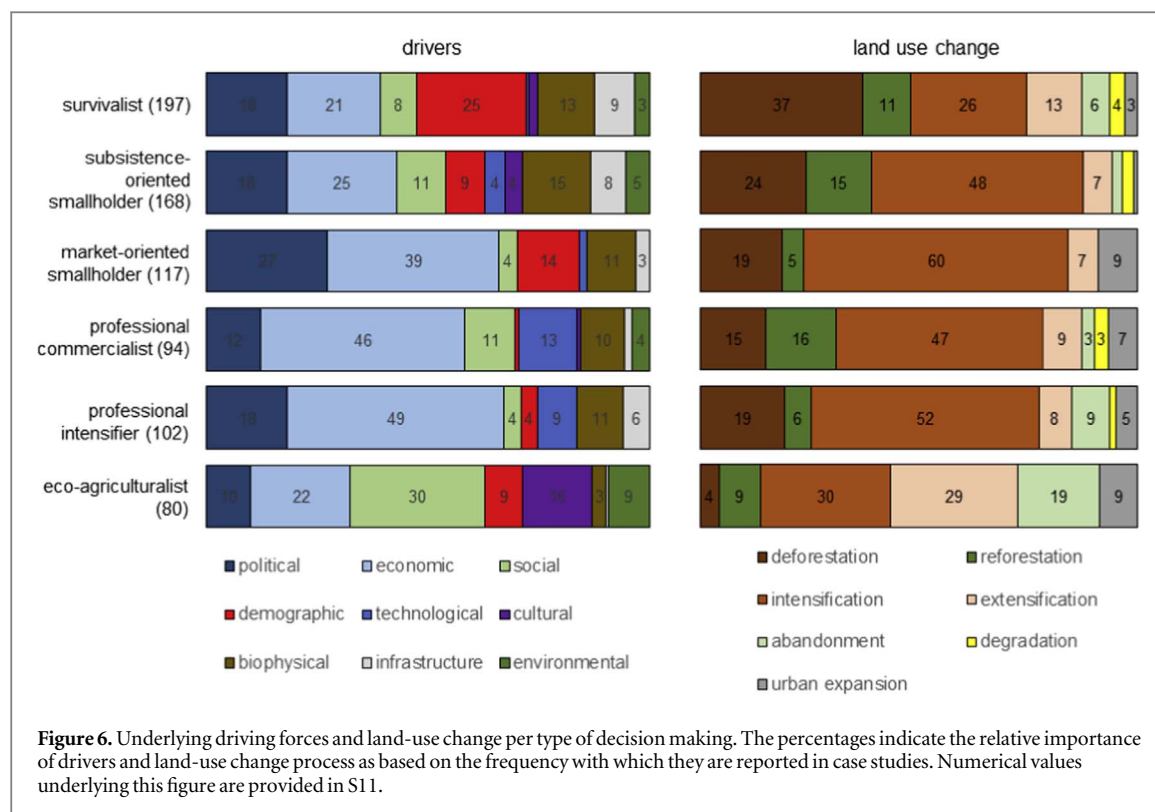
### 3.2.5. The professional intensifier

Professional intensifiers are large-scale farmers or companies oriented towards economic objectives (mean 9). They enjoy high land tenure security, and have a high power status and action control (figure 5, S10). They are similar to the professional commercialist, but are wealthier and have a lower appreciation of environmental values (1.45). They have the highest attitude towards change (mean 7.7), but are the least likely to diversify their land-use activities (S12). Most of their decisions (58%) result in intensification (figure 6). This decision-making type is, for example,

found for Australian full-time farmers (Sanderson and Curtis 2017) that own large farms (over 800 ha) equipped with irrigation. They are strongly oriented towards business, and operate their properties more intensively compared to other farmers in the area.

### 3.2.6. Eco-agriculturalist

The eco-agriculturalist, is very different from the other five decision-making types in the sense that different objectives are aimed for and the ability factors are rather high (figure 5). Decision-makers belonging to this type change land on the basis of lifestyle (mean 4.8) while accounting for economic objectives less than other decision makers (mean 3). Eco-agriculturalists have a progressive attitude towards change, but



also consider negative impacts on the environment when making a decision (environmental values mean of 6.8). Decision-makers belonging to this type are often well informed on the availability of state subsidies and are more likely to profit from state initiated agricultural programs or to join a nature conservation program. Contrary to other decision-making types, socio-cultural driving forces are the most common for this type (figure 6). Eco-agriculturalists are rather wealthy and have secure land tenure. They also enjoy many social resources (social connectedness mean 7.6, power status mean 8.3, action control 8.4). This decision-making type occurs the least frequent in land-use change literature, accounting for 11% of all land-change actors coded. The most common land-use change related to this type is agricultural intensification (30%), but also account for 37% of all reported agricultural land abandonment. An example of this decision-making type is an environmental scheme adopter from Scotland (Sutherland 2010). The example is a hobby farmer who reduced the intensity of her agricultural land and was highly enthusiastic about increasing plant diversity in her fields.

### 3.3. Representativeness analysis

Next to the already observed high dominance of indigenous communities within the case-studies a more formal representativeness analysis was conducted based on the location characteristics of the case-studies. A Kolmogorov–Smirnov test was used to find a potential bias in the included cases relative to the global distribution of several land-use relevant

conditions. Specifically, we tested the distribution of cases over location with respect to the tree cover, cropland cover, pasture area, irrigated area, altitude, slope, market accessibility, market influence, GDP, and population density. Results show that for all of these variables the distribution of the case studies was significantly different ( $p < 0.05$ ) from the global distribution. In other words, case study evidence on land-use decision-making is not representative for global conditions (see S6 for detailed results).

A closer look at the comparison between the global distribution of land use variables and their distribution over case study sites shows that cases are found more often in areas with cropland and pasture (see figure S6.1). This can be explained by the large number of farmers included in the sample. Moreover, this comparison reveals that cases are generally found in places with a slightly higher population density, GDP, market influence and market access. These findings are consistent with the observation that most decision makers are farmers, and occupy areas with access to markets and other people. Agricultural land intensification or forest conversion to agricultural land (deforestation) can occur due to higher market demands or changes in food consumption. Many case studies from the sample investigated the transition from subsistence agriculture to semi-subsistence or commercial agriculture, which is more likely to occur in the proximity of markets. Good market accessibility also attracts regional migration, which potentially increases the area of agricultural land-use in some areas. Markets are often located in urban centers, which explain the high values of population density in the



sample. A second trend occurring in or nearby urban areas is the diversification of livelihoods, which often involves seeking off-farm work (e.g. shop keeping, tourism, service industry) in cities. This trend is connected to agricultural land disintensification, land abandonment and reforestation.

Cases are also found on steeper slopes than the global distribution, indicating a focus on more marginal areas. Steep slopes are prone to environmental degradation (erosion) and often hold challenges for agricultural use. These areas are more likely to be subject of land-use changes in terms of de- or reforestation and are therefore more likely to be chosen for research given the land degradation challenge and often attractive scenery.

## 4. Discussion

### 4.1. Decision-making mechanisms in land-use change

We present a first systematic global synthesis of local scale land-use change decision-making. Distinctive decision-making mechanisms were identified across the case studies, characterized by a combination of objectives, attitudes and ability. These decision-making mechanisms were identified across multiple land-use change processes, while previous approaches often focused on one type of land-use change (Geist and Lambin 2004, Keys and McConnell 2005, Lambin and Geist 2006, Knowler and Bradshaw 2007, Rey Benayas 2007, Seto *et al* 2011). This approach allowed us to assess whether certain decision mechanisms are more disposed to specific drivers or land-use change processes. Within the diverse context of decision-making in the different case studies, we found clear patterns in the relations between the type of decision-making, the underlying driving forces and the resulting land-use choices. Most of the decision-makers (64%) reported in the literature are attributed to the three types of decision makers that are generally poor and that cultivate smaller amounts of land (survivalist, subsistence-oriented smallholder, and market-oriented smallholder). Even though the abilities of these decision-making types are similar, they differ in their objectives and attitudes and, broadly, describe a range from land-use purely aimed at survival towards more market-oriented small-holder farming. Survival and livelihood objectives often occur together with deforestation, while economic objectives most often result in agricultural land intensification. Land-use decision-making is, thus, different in different contexts, but also in different development stages. Often the transition from survival dominated land-use toward more market-based land-use decision making is related to a development trajectory (Lambin *et al* 2001).

Regardless of the type of decision-maker, economic objectives are often dominant, which justifies

much research and land-use modelling that uses an economic rationale as assumed decision-making. However, there has been growing critique on economic centered approaches (Levine *et al* 2015). Many authors argue that decision-making is not solely based on economic gain, but on a combination of factors (An 2012, Levine *et al* 2015, Nualnook *et al* 2016), which we confirmed in this review. The results indicate that an economic rationale alone does not allow for a complete description of land-use change decisions, as it lacks important factors such as attitudes and ability and, in many cases, we found economic objectives being jointly reported with other objectives.

The attitude towards change is an important factor in carrying out any intended decision. We found that a positive attitude towards change is often connected to economic objectives. Actors with less positive attitudes to change are more conservative and tend to reject new rules and neglect legislation, which most often occurs together with deforestation (survivalist). As can be expected, a positive attitude towards environmental values would most often occur with reforestation or agricultural land disintensification, but the results from the review only partly support this. The subsistence smallholders, for example, show the highest attitudes towards environmental values but are primarily connected to intensification and deforestation. Nevertheless, this decision-making type accounts for 27% of the cases reporting reforestation, which is the most across all decision-making types. This could be explained by a high share (10%) of shifting cultivation resulting in forest regrowth reported for this decision-making type. In contrast, the eco-agriculturalists with the second highest environmental values are most often related to agricultural disintensification (28%).

Despite the alarming rate of global deforestation (Keenan *et al* 2015), only 21% of all reported land-use change processes documented in the case studies concern deforestation. Most decision-makers in this review are land-managers who cultivate land, which was inherited or already cultivated by their predecessors. These land managers often pursue a certain livelihood strategy, mostly resulting in diversification (68% of all cases, S12) or intensification. The relatively high frequency of reforestation (107 decision-makers) amongst the sample as compared to agricultural abandonment (60) and urbanization (57) may reflect the significance given by researchers to understanding the decision-making underlying reforestation.

While we assumed that all cases were representing decision-making in the most objective manner, underlying assumptions or guiding theory have influenced the outcomes of many studies. In a lot of case studies a *Homo economicus* inclined approach towards decision-making is assumed, meaning that decision-making is often approached as rational maximization of utility or self-interest (Levine *et al* 2015). These implicit assumptions are likely to reveal financial factors, such as income, savings or government subsidies,

as the strongest determinants for decision-makers to implement land-use change (Nualnoom *et al* 2016). Given this dominance of economic theory as a leading principle for case-study investigation, the results from this synthesis may more strongly reflect economic objectives and financial ability as important factors in the decision-making process. It is likely that also other assumptions and pre-conceptions have influences that reported findings on the decision-making process in various of the included studies. Such bias cannot be separated from the outcomes and one should account for the possibility that the results also, to some extent, reflect the perceptions and assumptions of the researchers conducting the included case studies.

#### 4.2. Implications

Improved knowledge of human decision-making in land-use change is crucial to advance our understanding of how underlying drivers of land-use change are moderated through human agency in different ways (Verburg *et al* 2019). Insights in decision-making process at individual level can help to ensure policies that are tailored to the diverse needs of land managers.

Insights in decision-making mechanisms help scientists to better understand the complexity of human and natural systems and can improve existing agent-based models in land-use change (Magliocca *et al* 2015). Land-use change models often rely on computer simulations or extrapolations of historic data, which are commonly correlated to spatial variables. Decision making in these models is often not explicitly represented and, thus, not differentiated between different actors. Although different agent-based models apply allow the representation of differences in decision-making, many of these are not selected based on empirical evidence or the specific contextual conditions (Brown *et al* 2017, Groeneveld *et al* 2017, Huber *et al* 2018). Our results provide an empirical basis for this and indicate that there are distinct decision mechanisms in land-use change worldwide. This variation (and its temporal dynamics) should also be accounted for in land-use modules of global models.

Research at local case-study level that explicitly aims at exploring decision-making mechanisms of land managers needs to improve the documentation of the decision-making mechanisms and the factors that influence the mode of decision-making and resulting land-use change trajectories. Many case studies focus on underlying driving forces, thereby neglecting the plethora individual objectives and motivations of land managers. Many case studies only poorly documented the decision-making mechanisms hampering comparison and making a synthesis like ours very difficult. Furthermore, many case studies are conducted at locations which are either easily accessible, attractive for researchers, or where currently large land-use change is happening. Case studies conducted in regions that have little access to

infrastructure and markets, or that have seen little change in past periods (such as some of the core agricultural landscapes worldwide) may provide additional insights into decision-making mechanisms worldwide.

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#### Data availability statement

The data that support the findings of this study are openly available at <https://hdl.handle.net/10411/YKVOA>.

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